

BELLCOMM, INC.

SUBJECT: AMDA/OWS Solar Array Power System
Capability-Inertial Orientation
Case 600-3

DATE: June 9, 1967

FROM: J. D. Dunlop

ABSTRACT

The inertially orientated AMDA/OWS solar array-battery power system capability is discussed. The continuous power available from the solar array-battery power system is dependent on the solar array performance, the regulating components and battery charging efficiency, and the radiation degradation of the solar array. The effects of each of these variables on the power system performance is presented.

(NASA-CR-154816) AMDA/OWS SOLAR ARRAY POWER
SYSTEM CAPABILITY INERTIAL ORIENTATION
(Bellcomm, Inc.) 9 p

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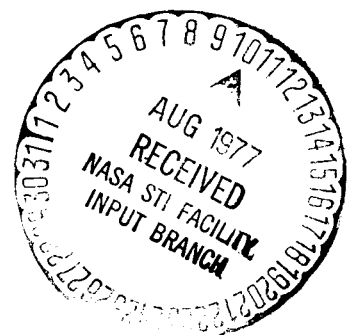
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MEMORANDUM FOR FILE

1.0 INTRODUCTION

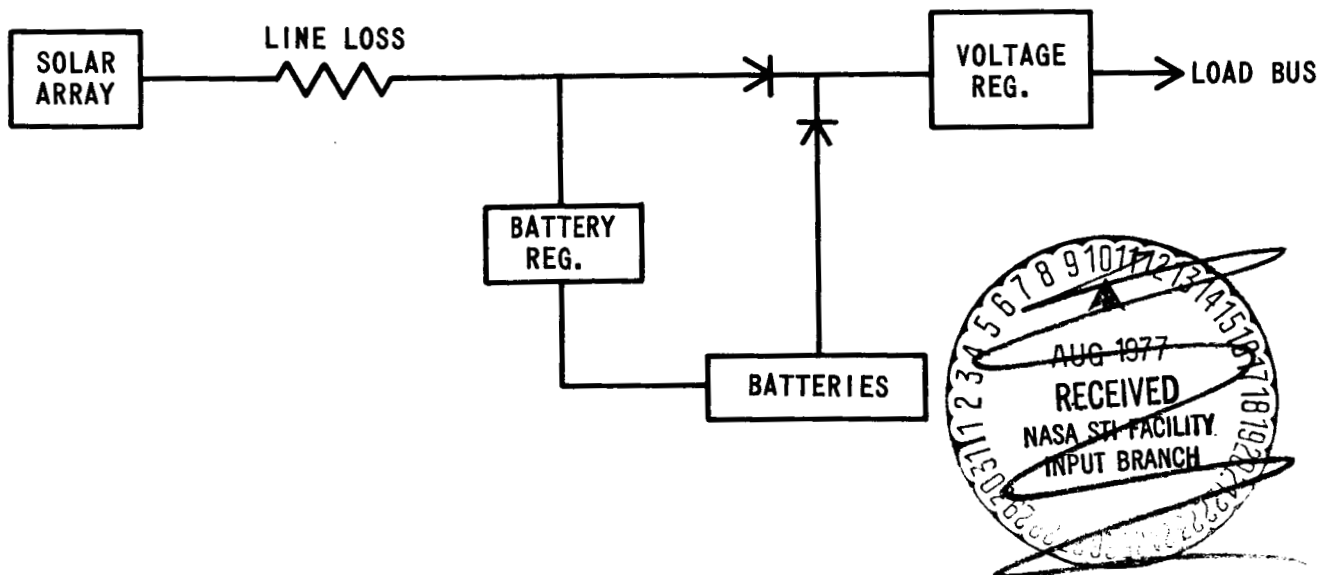
There are two major areas for consideration in determining the performance of solar array electrical power systems: The electrical power generation capabilities of the solar array in direct sunlight, and the overall power system including batteries, voltage regulation, battery chargers and light/dark ratios.

The estimate of the generation capacity of the array is dependent on such items as the solar cell efficiency, solar array temperature, radiation degradation, and the amount of conservatism in the design.

The overall power system relates the ratio of continuous power which can be delivered to the load to the power generated by the solar array.

2.0 SCHEMATIC OF THE OVERALL POWER SYSTEM

Below is a simplified block diagram of the overall power system.



The relationship between the average light time solar array power and the continuous power delivered to the AMDA bus is determined as follows:

$$P_{SA} = \left[P_L + (P_D) \left(\frac{T_D}{T_L} \right) \left(\frac{100}{\text{Reg B}} \right) \left(\frac{100}{B} \right) \right] \left[\frac{100 + \text{Line Loss}}{100} \right] \left[\frac{100}{\text{Reg V}} \right]$$

P_{SA} = Solar Array Power

P_L = Bus power, light time

P_D = Bus power, dark time

Reg B = Battery regulator efficiency

B = Battery charge efficiency

Reg V = Voltage regulator efficiency

T_D = Dark time per orbit

T_L = Light time per orbit

Sample calculation

Assume:

$$P_L = P_D$$

$$\text{Reg B} = 85\%$$

$$B = 65\%$$

$$\text{Reg V} = 85\%$$

$$T_D = 35.8 \text{ minutes}$$

$$T_L = 58.8 \text{ minutes}$$

$$\text{Line Loss} = 15\%$$

$$\frac{P_{SA}}{P_L} = \left[1 + \left(\frac{35.8}{58.8} \right) \left(\frac{1}{.85} \right) \left(\frac{1}{.65} \right) \right] \left[1.15 \right] \left[\frac{1}{.85} \right] = 2.835$$

For the above assumptions the solar array must deliver 2.835 KW during the light period to supply 1 KW continuous to the load. The light/dark times used in this example are for a 270 NM circular orbit, and a 90° angle of incidence between the sun line and the orbital plane (i.e. zero degree β angle).

3.0 CONTINUOUS POWER AVAILABLE FROM THE SOLAR ARRAY

With the assumption that the power requirement during the dark and light time is equal, the EPS output capability is shown in Figure 1 as a function of the β angle. Solar panels and arrays were assumed to be in the following configuration:

Solar Panels: (14.25 inches x 18 inches) 1.77 ft^2 , 466 panels are used in the present S-IVB solar array configuration. Each panel contains 370 2 cm by 2 cm cells.

Solar Arrays: 8 arrays are used; 6 large arrays ($\sim 110 \text{ ft}^2$ each) composed of 63 panels, and 2 arrays ($\sim 82 \text{ ft}^2$ each) comprised of 45 panels. Total Array Area $\sim 824 \text{ ft}^2$.

An explanation of each of the four curves shown follows:

Curve 1. This curve represents the preliminary MAC estimate of the continuous available power. The electrical power system has been redesigned to improve the performance.

Curve 2. This curve represents the MSC (MAC) estimates of the continuously available power as presented in the Electrical Power Systems Panel at MSC May 24, 1967. Improvements were: to reduce the line loss by a factor of four by doubling the output voltage from the panel, and to increase the voltage and battery charging regulator efficiencies to 93%.

Curve 3. This curve represents the estimated available power at the start of the mission and would be applicable for AAP-1/AAP-2 missions. Curve 2 is the power available at the end of one year. The difference is due to U.V. radiation degradation of the solar array cover slides over one year.

Curve 4. In almost all solar array designs a safety factor of 20 to 30% is allowed for the array performance. In Reference 1 Arvin Smith states; "A derating of at least 20 percent is considered necessary to establish acceptable confidence in power source success." Curve 4 is the continuous power without the 20% margin in the

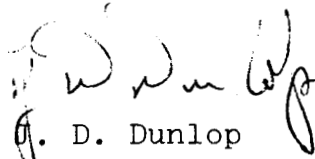
array performance, and also assuming that the array temperature is 55°C instead of 70°C . The steady state temperature for solar arrays with proper thermal coating has been demonstrated to be 55°C . It is not clear why MSC is using 70°C .

Table I summarizes the assumptions used to generate each curve.

Summary

The solar array EPS will most probably supply continuous power as shown in Curve 4. However, including a 20% derating of the array and a 70°C array temperature the performance for AAP-1/AAP-2 is shown in Curve 3. At the end of one year U.V. radiation degradation could reduce the power as shown to Curve 2.

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Attachments
Figure 1
Table I
References

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Table I

Figure 1 Curves	(1)	(2)	(3)	(4)
Panel output at reference Temp. of 25°C, watts.	16.5	16.5	16.5	19.8
Panel output at operating Temp. watts.	11.7	11.7	13.0	16.7*
Watts/ft ²	6.6	6.6	7.35	9.4
Battery charger efficiency	85%	93%	93%	93%
Voltage regulator efficiency	85%	93%	93%	93%
Line loss %	15%	4%	4%	4%
Panel temperature °C	70	70	70	55
Battery efficiency	65%	65%	65%	65%
U.V. degradation	10%	10%	0	0
$P_{SA}/P_L: \beta = 0^\circ, T_D/T_L = \frac{35.8}{58.8}$	2.835	2.25	2.25	2.25
$P_{SA}/P_L: \beta = 52^\circ, T_D/T_L = \frac{27.63}{67}$	3.37	1.88	1.88	1.88

* Panels have been produced which exceed 17 watts/panel in space; 16.7 watts/panel used in report; LMSC. See Ref. 2.

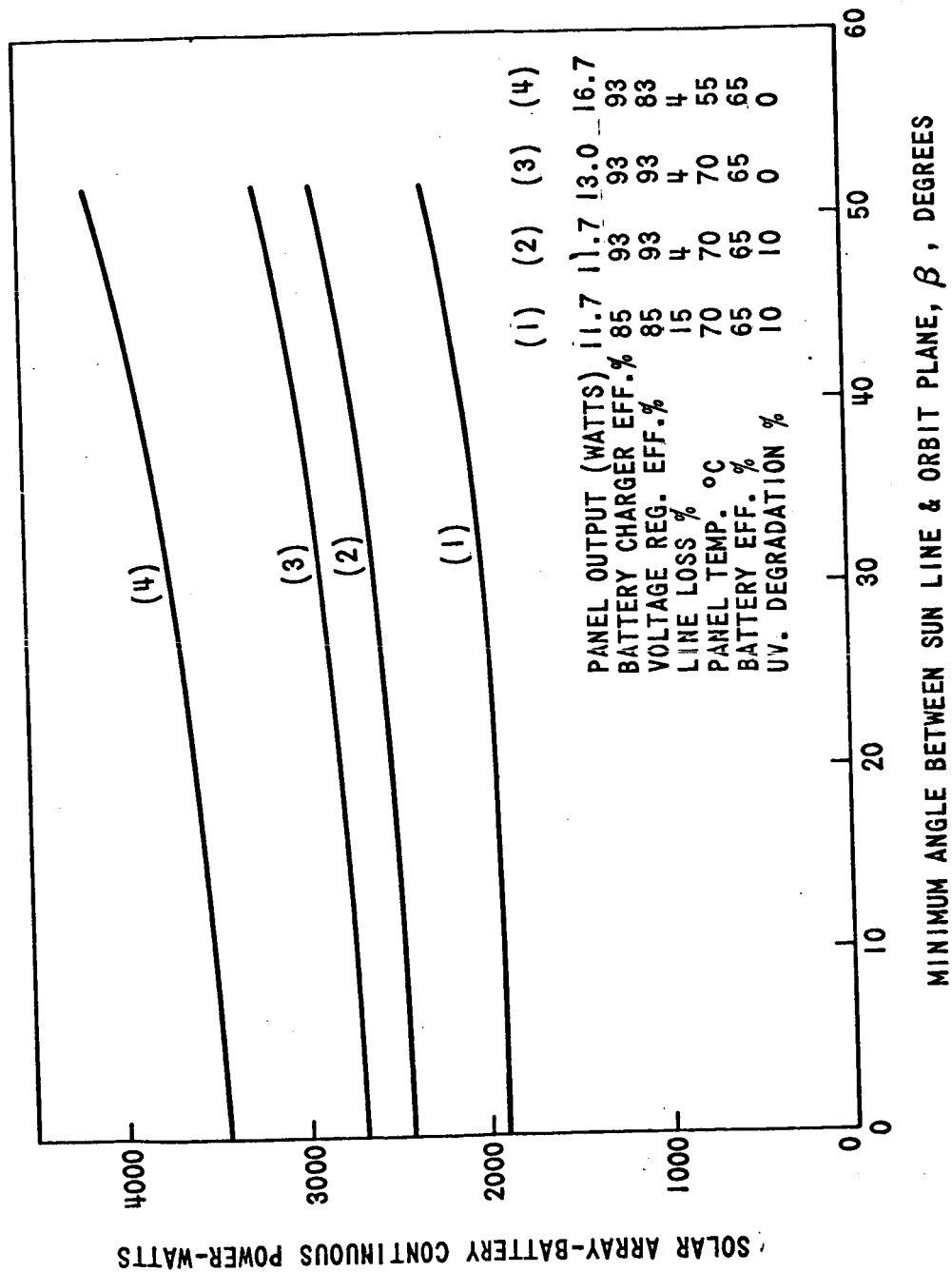


FIGURE 1 CONTINUOUS POWER vs. β ANGLE FOR INERTIAL ORIENTATION OF THE S-IVB WORKSHOP

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REFERENCES

1. Electrical Power for The Scientific Exploration of The Solar System, Arvin H. Smith, NASA RN65-15038, January 26, 1965.
2. Technical Feasibility Study, S-IVB Solar Array Installation, March 18, 1961.

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